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The Status of the Riparian Forests in the Naryn Valley of Kyrgyzstan: Conservation and Sustainable Development

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Abstract

Conservation and restoration of riparian forests are important for strengthening river banks and preserving biodiversity as well as for mitigating impacts of climate change. Increasing temperature and climate variability, flooding and drought, alteration of the intensity of precipitation and melting glaciers in high mountain areas affect the physical condition of natural resources as well as natural hazards. Climate change might cause larger and potentially hazardous summer floods. The temporary storage of floodwaters in the floodplain areas reduces the flood risk downstream. In this paper, the current state of natural resources and the benefits of mountain floodplain forests is investigated. The satellite imagery was used to study the landscape changes for mapping the investigation areas. The assessment of changes is necessary for the further development of restorative plan for floodplain rivers. The results provide information on options for management and provide assistance to the local authorities engaged in the integrated management of natural resources.

Keywords

Riparian forest; Floodplain; Ecosystem service; Degradation; Climate change

Introduction

The formation of floodplains is accompanied by a continuous exchange of material between the floodplain and channel deposits (Makkaveev, 1998; Kenneth and Brooks, 2003). The potential ability of floodplain decreases at peak of discharge (Brandt, 2000; Makkaveev, 1998; Hupp, Pierce and Gregory, 2009). Furthermore, it is important to study the hydrological impact resulting from the change in land use (Merritt and Wohl, 2003; Wohl, 2005). Changes in vegetation cover also influence sediment transport (Harrison and Keller, 2007; Benjarkar *et al*., 2011). Therefore, land use on the floodplain area and change of vegetation composition are important factors affecting the processes in a river system.

Research on understanding the landform development of rivers is important and it gives clarification on the individual cases of the explored river system. The geomorphic shape of the river system, basically, depends on the hydrological conditions of intermittent, short and constant flows as well as the availability of sediment. These factors are important for the identification of the effects and mechanisms of short-term hydrological changes (Gregory, Macklin and Walling, 2006). Analysis of the location of reach boundaries helps interpret controls upon downstream patterns of river. The fluvial depositional compound helps depict the river changes within processes such as hydraulic, climatic, tectonic and human activities (Thorndycraft, Benito and Gregory, 2008). The frequency and magnitude of flood leads to having a particular type of riverbank formation.

Anthropogenic impact on natural floodplain ecosystems increases the amount of water erosion. Deforestation makes the floodplain more susceptible and vulnerable to bank erosion, as the stabilizing influence of the riparian vegetation is reduced (Simon and Collison, 2002). The highest potential for natural hazards related to bank erosion is in areas where deforestation of floodplains takes place near the villages. Local people use fuelwood, timber and construction materials. In addition, they use floodplains for livestock grazing from autumn to late spring. Consequences of the anthropogenic influence are not only an increase of the flood risks, but also river banks are more exposed to erosion.

Geomorphologic dynamics is naturally occurring on floodplains. These process within a river system appear as accretion and erosion of river banks. Nowadays, research focuses on the floodplains of regulated rivers to foster restoration to a more natural state (Tockner, Schiemer and Ward, 1998; Schiemer, Baumgartner and Tockner, 1999; Downs and Thorne, 2000; Collins and Montgomery, 2002; Junker and Buchecker, 2007). Existing research about the Naryn River refers to studying the retention of glaciers (Aizen, Aizen and Melack, 1995; Kriegel *et al*., 2013), changes in the hydrological cycle and water management and transboundary issues related to hydropower cascades down the river (Giese *et al*., 2004). There is a lack of information on the natural character of the geomorphology of the Naryn River. So far, no comprehensive data is available yet. To fill this gap in the literature, this paper contributes to a better understanding of the natural dynamics of the Naryn floodplains. The main goal of this study is the analysis of the range of formation processes of Naryn River floodplains over time. For this, the migration of pathways of the river banks was analyzed using the visual interpretation of Landsat imagery.

Method and materials

Study Area

The study area is the Naryn catchment, which is located in the north-western part of the Central Tien Shan. The Naryn River is the main tributary of the Syr Darya being the main feeder of the Aral Sea. It supports not only the irrigation but also the electricity sector of Kyrgyzstan, and it influences the agricultural and economic condition of neighbouring countries too. It begins with the confluence of the two rivers Big Naryn and Small Naryn, fed by the glaciers of Ak-Shiyrak of the Central Tien Shan. Most of the volume of its

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water is collected from the mountains and flowing into the mountain valley of the Inner Tien Shan. Climatic conditions of the Naryn River are characterized by a continental climate with cold, long winters and short summers. According to the Naryn meteorological station data, the average annual temperature for 1999-2016 was 4.3 °C. The coldest month is January with an average temperature of 16.4 °C and warmest is July with an average temperature of 17.1°C. The average annual rainfall is about 303 mm. The intense precipitation occurs during the spring and summer. The fluctuation of the value of air temperature with a maximum of 37.8 °C and with a minimum is 26.6 °C.

The main discharge of the Naryn River results from the melting of snow and glaciers. The intensity of spring floods is observed in the months of June and lasts until September. Overall, about 2-% of the basin area is occupied by glaciers of Central Tien Shan Mountains and their contribution to the volume of flow in flooding is significant (Aizen, Aizen and Melack, 1995; Kriegel *et al*., 2013). The watershed is used for agricultural activities and includes uplands, hillslopes, pasture, agricultural and urban lands.

The Naryn shows a diverse morphology along its course with narrow gorges right upstream from the Toktogul Reservoir. Figure 1 shows the floodplain areas of the Naryn River. Two areas were selected for the study focusing changes on the lateral migration of floodplains areas 1 and 2.

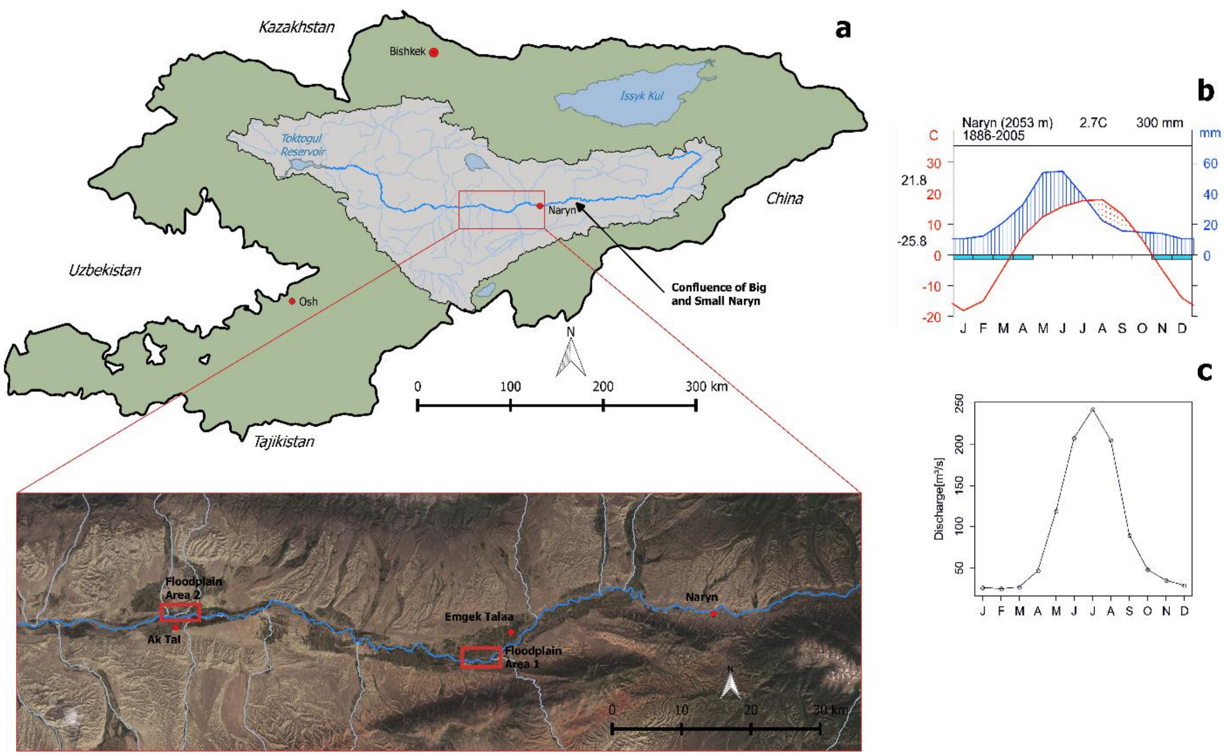

Figure 1: The study area; 'a' shows the regional overview, 'b' the climate diagram of Naryn City; and 'c' the hydrograph of Naryn City

The methodology of this study consists of the analysis of the SRTM-1 digital elevation model (DEM) and Landsat imagery. The DEM analysis includes watershed delineation to extract the length of the stream with elevation distribution in the catchment of river. It also used r.stream modules in GRASS GIS (Jasiewicz and Metz, 2011). The geographic location of the watershed considered for this study is expanded from the upper Tian Shan Mountains to the Toktogul Reservoir.

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To study channel migration, multi–temporal Landsat data from 1972 to 2015 was used. Images from the flood season (July and August) with a sufficiently small cloud cover were selected. Landsat imagery was used, along with imagery from MSS, TM and OLI. The riverbank changes were manually digitized using a false colour composition of the imagery. Combination of Landsat 5 (TM) 7-5-3 and Landsat 8 (OLI) 7-6-4 was used. In this combination, water bodies become clearly visible. The analysis was performed using ArcGIS and MS Excel. In addition to these large-scale investigations, the structure of the floodplain ecosystem was assessed locally based on high-resolution World-View2 imagery.

To analyze the lateral channel bank changes, the method of Kummu *et al*. (2008) was used. The river was splitted into sub-reaches of 1 km length as shown in figure 2 and 3. For this analysis, the changes of the riverbank location were measured five-times. The erosion and accretion have been assessed for the left and right banks separately.

Results

The geomorphological shape from the upper to the middle part of the Naryn River is characterized by various forms of force by the terraces and braided river sections (Figure 5). The development of topographic surfaces in large flood events encourages the deposition of bedload materials on mid-channel bars. The pattern of geomorphic units showed a high dynamic over the past more than 43 years. The recent floodplain structure can be described as a braided river channel with extended bars and islands confined by a discontinuous high terrace. In the reaches from 2 to 7 in figure 2, the position of the river channel shifted towards the right river bank following the flow energy.

The investigated floodplain areas have a discontinuous high terrace formation (Figure 3). In the central part of the valley, formed islands are separated by several gravel bars (Figure 3). Large deviations and flow velocity cause the transfer by the river of a huge amount of suspended sediments (Fryirs and Brierley, 2013). The main deposition consists of both -suspended and bedload during flood events. The morphology of the investigated floodplain areas is partitioned into small and big islands. Islands and bank parts are covered with small pioneer forests (Figure 4). The vegetation in floodplain areas consists of species such as poplar (*Populus nigra),* willow *(Salix* spp.*),* and shrubs e.g., honeysuckle (*Lonicera* spp.), sea buckthorn (*Hippophae rhamnoides*), Cotoneaster (*Cotoneaster* spp.), Spirea (Spiraea spp.), Tamarisk (*Tamarix* spp.), Rosa (*Rosa cinnamomea*) and Oleaster (*Elaeagnus angustifolia*). Of these, Populus nigra is the dominant species, along with Tamarix spp., Lonicera spp. and Hippophae rhamnoides. Floodplain forests have a relatively low tree species cover of 26-50%. Therefore, vegetation at different heights differs both in species composition and in a coverage area.

Analysis of fluvial geomorphological features through Landsat imagery of the floodplain provides a detailed understanding of channel migration. Stream power variability along unstable banks leads to a change in the channel in the right bank of the Naryn River. Figure 5 shows the range of alteration in riverbeds along the full length to the floodplain areas 1 and 2. Patterns of sediment erosion and deposition in different flow stages during the inundation period shape the floodplain. A comparison of the channel width and pattern of the river length shows the range of dynamics in the river channel. The figure 5 also depicts the detailed information of the meanders and braided structures with its evolution pattern. For the understanding of channel change dynamics, the investigated upper zone of the main tributary i.e., Big and Small Naryn River, is presented in figure 5.

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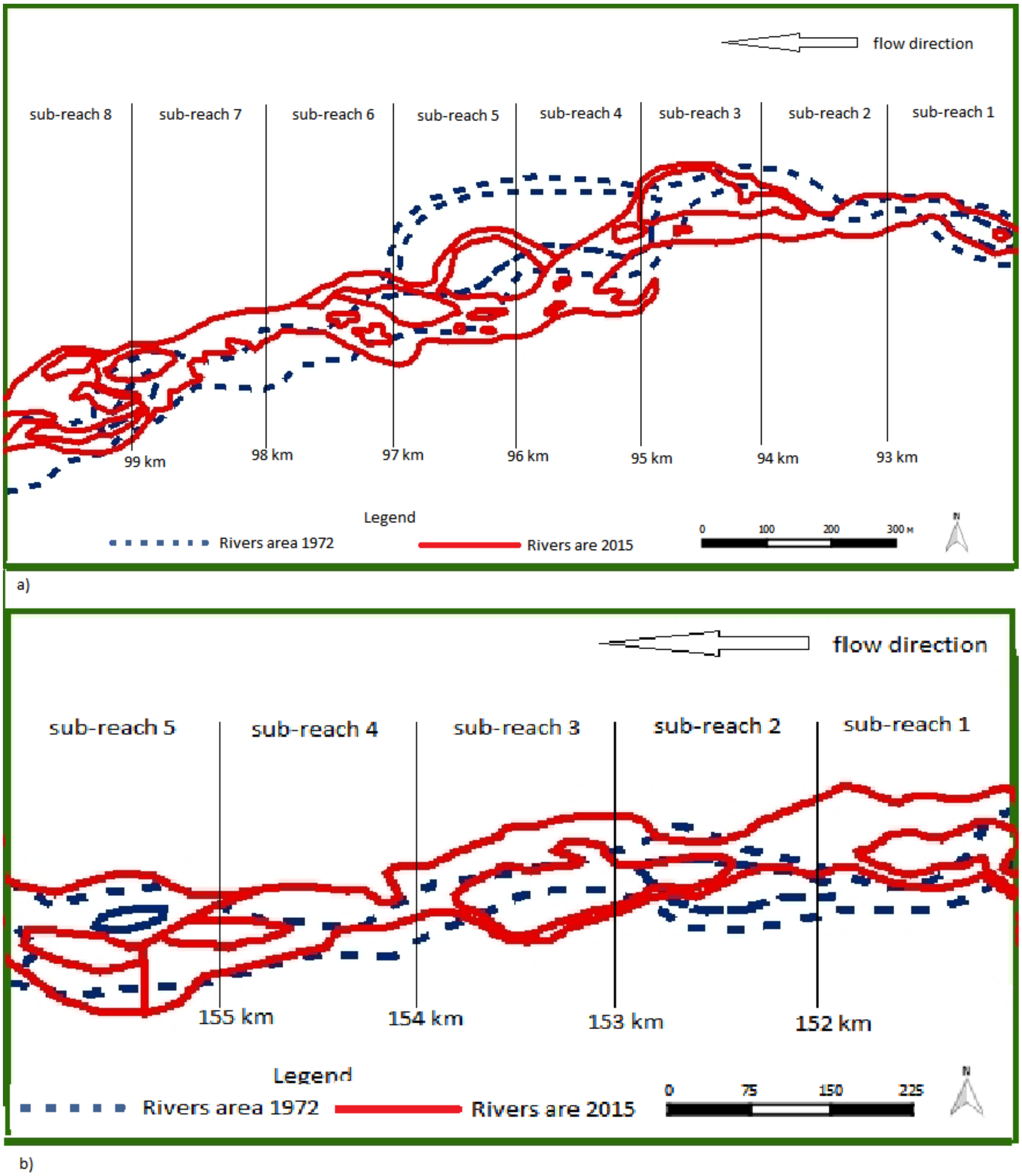

Figure 2: Division of floodplain areas 1(a) and 2 (b) -to the sub-reach boundaries to analyze the lateral migration

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Figure 3: Structure of geomorphologic units of floodplain area 1 along the Naryn River


Figure 4: Island formation in floodplain area 1and overview over floodplain area 2

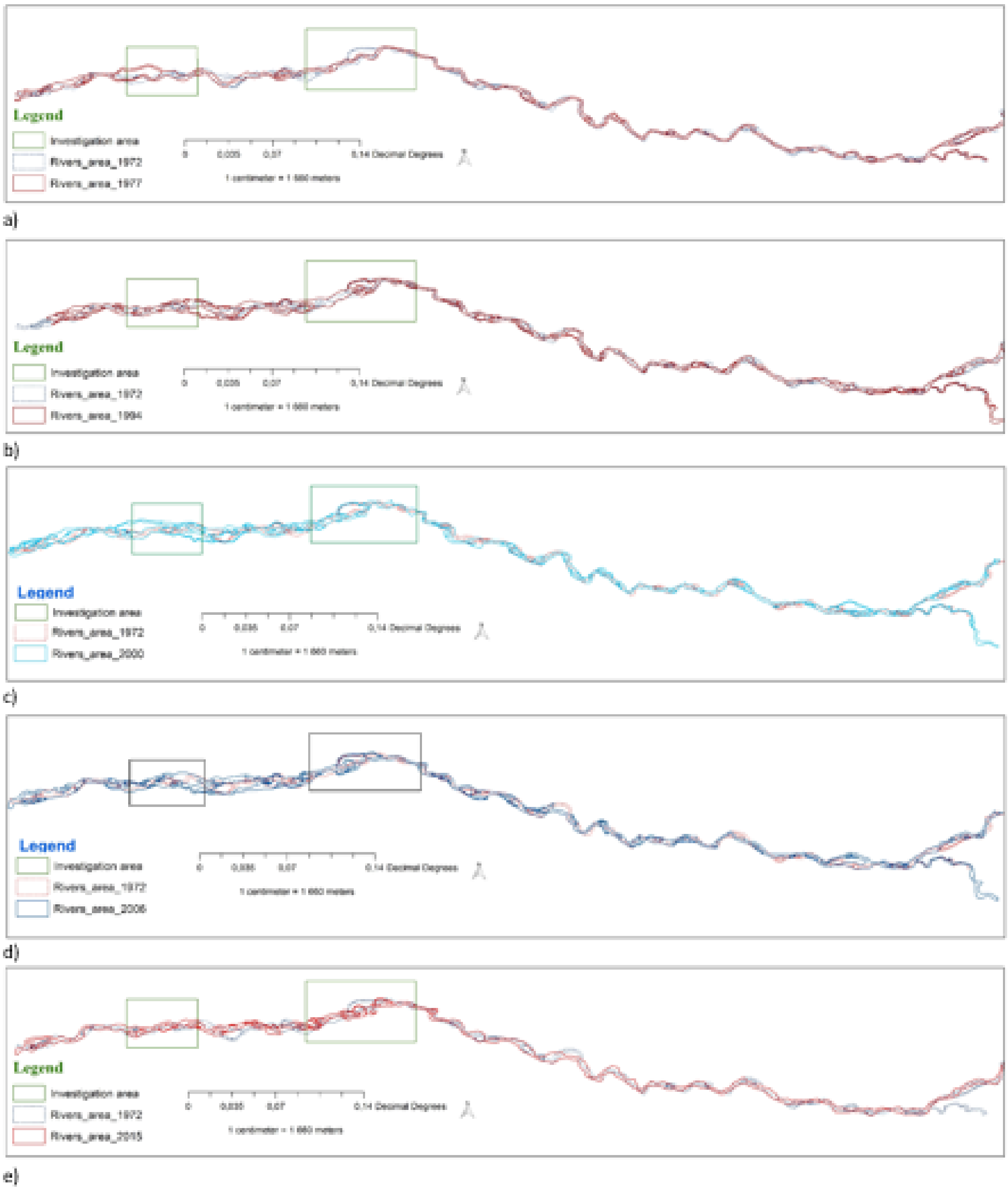

Figure 5: Lateral migration of pathways of the Naryn River for 1972-1977(a), 1972-1994(b), 1972-2000(c), 1972-2006(d) and 1972-2015(e)

To identify the places on the floodplain areas where erosion and accretion occurred, a method proposed by Kummu *et al*. (2008) was used. The erosion areas of the bank movement rates are plotted as a function of distance along the riverbanks of the two floodplain areas. The results of the calculation are presented in figure 6 and 7 for the right and left banks of the selected areas along the Naryn River.

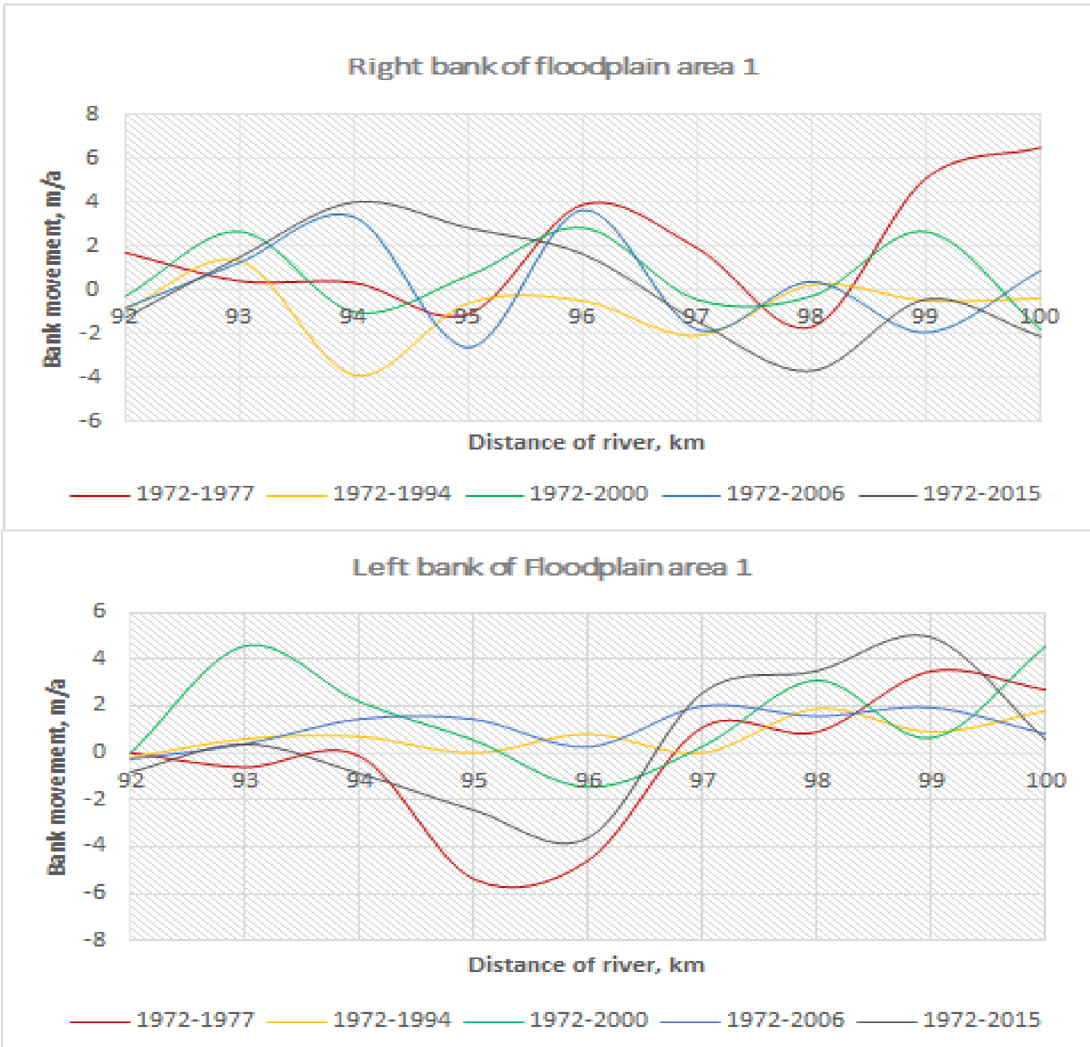

Figure 6: Rates of bank movement for floodplain area 1

The changes in bank location for each time period are indicated in table 1. The analysis for 1972–2015 shows an average bank accretion of 0.8 m/a (meter/accretion) and an erosion of 0.4 m/a for the floodplain area 1. The average bank accretion of 0.6 m/a on the left bank and 1.0 m/a on the right bank for the floodplain area 2, with average erosion rate of 0.5 m/a and 0.3 m/a, respectively. It is observed that accretion of right river bank had occurred during 1972-1977.

Table 1: Annual average bank erosion and accretion rates (m/a) in the floodplain area 1 for the 1972–2015. Erosion and accretion rates have been analyzed separately for the left and right banks of the river

Accretion or Erosion	*1972-77*		*1972-94*		*1972-00*		*1972-06*		*1972-15*	
	Left bank	*Right bank*	*Left bank*	*Right bank*	*Left bank*	*Right bank*	*Left bank*	*Right bank*	*Left bank*	*Right bank*
Accretion (m/a)	1.636	3.948	0.304	0.070	0.566	0.313	0.290	0.278	0.277	0.231
Erosion (m/a)	2.142	0.559	0.009	0.403	0.052	0.138	0.008	0.212	0.180	0.208

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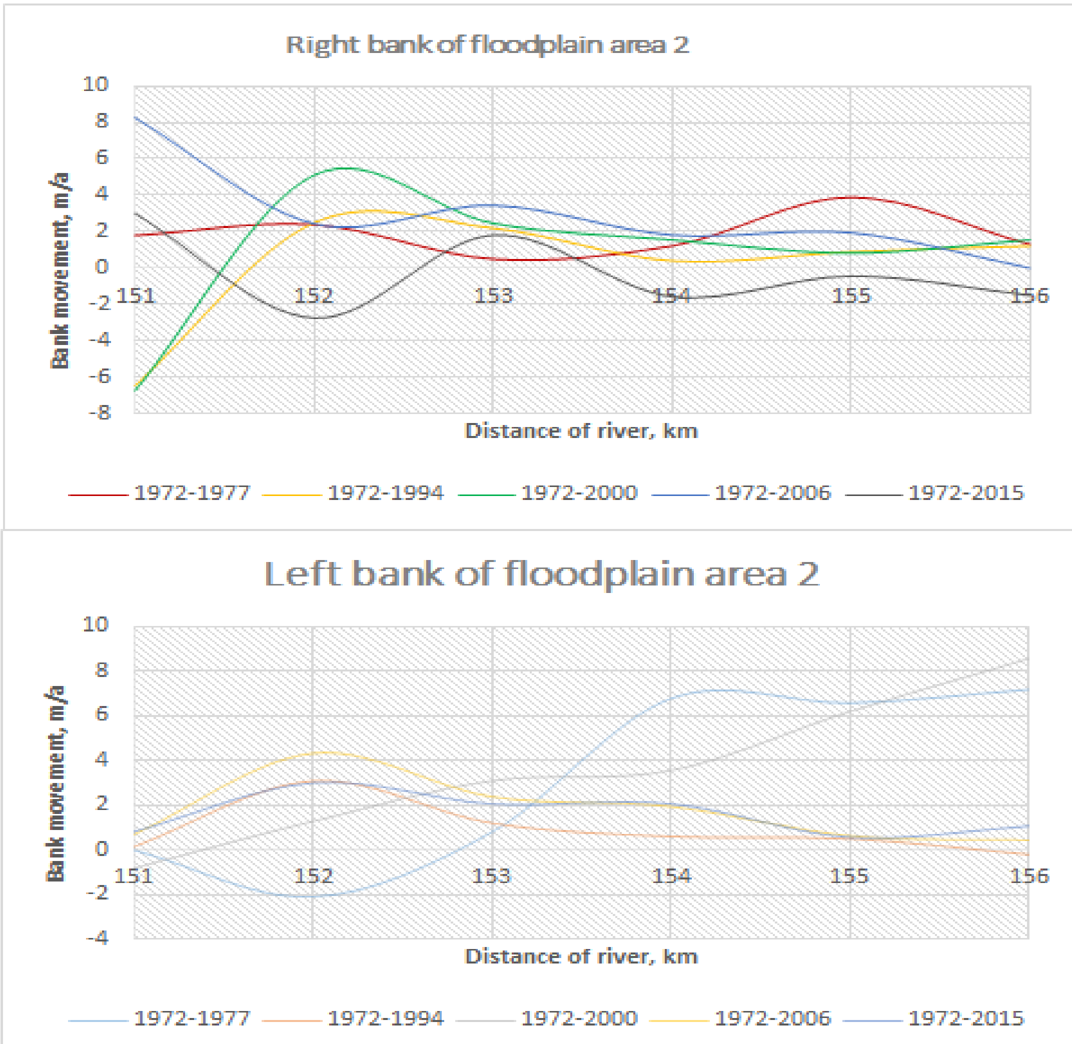

Figure 7: Rates of bank movement for floodplain area 2

Table 2: Annual average bank erosion and accretion rates (m/a) in the floodplain area 2 for the 1972–2015. Erosion and accretion rates have been analyzed separately for the left and right banks of the river

Accretion or Erosion	1972-1977		1972-1994		1972-2000		1972-2006		1972-2015	
	Left bank	Right bank	Left bank	Right bank	Left bank	Right bank	Left bank	Right bank	Left bank	Right bank
Accretion (m/a)	4.263	0.000	0.251	0.327	0.810	0.410	0.306	0.526	0.222	0.112
Erosion (m/a)	0.420	2.216	0.009	0.294	0.029	0.241	0.100	0.100	0.000	0.145

Figure 8 gives the hydrograph of Naryn River. The seasonal cycle is characterized by a maximum discharge in July, which starts to decrease again from September.

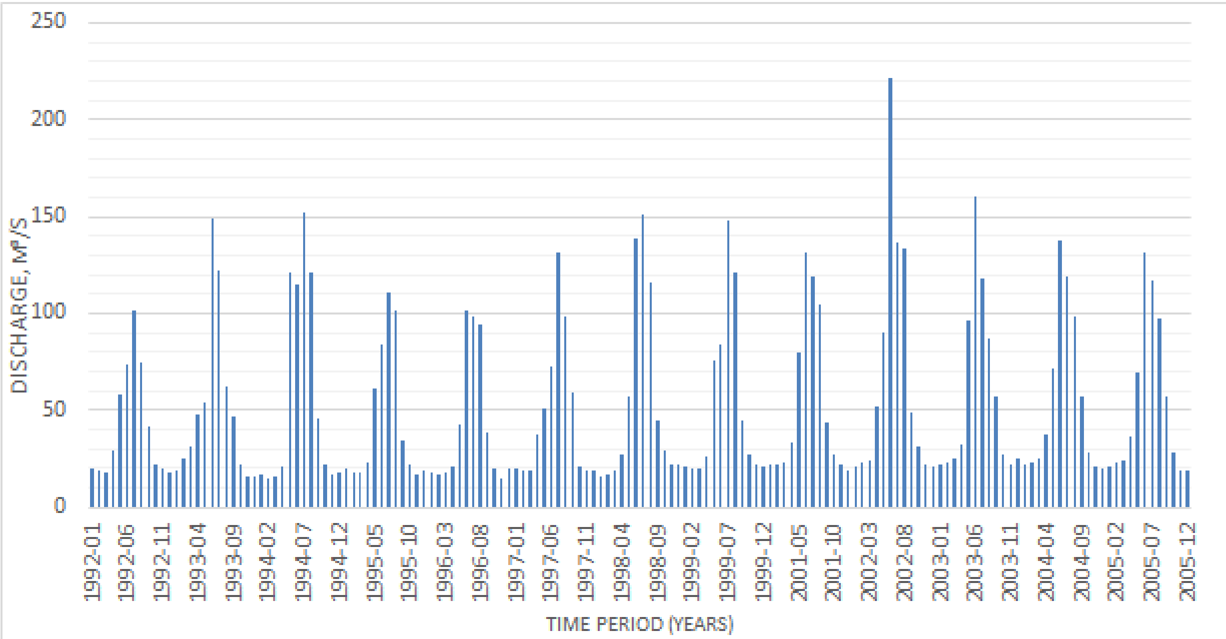

Figure 8: Long-term hydrograph of Naryn River from 1992-2005. The hydrological data obtained from http://neespi.sr.unh.edu [Accessed on 5 September 2020]

Climate change is leading to an increase in temperatures and, consequently, to a reduction in glacier retention. In the territories of the Naryn river basin, the coverage with glaciers is about 2%, they are exposed to the eastern side of the mountains (Aizen, Aizen and Melack, 1995; Kriegel *et al*., 2013). During the floods there is a supply of sediments and the deposition rates in the channel can increase.

Environmental zoning maps are essential for the sustainable management of natural resources and reflect ecosystem services, ecosystems and their components (Figure 9 and 10). Mapping of floodplain forests helps plan and manage effectively the activities of the Forestry Department and local self-government to improve soil protection and water protection functions. The figure 9 indicates the results of processed Landsat imagery enabling the identification, mapping and investigating the actual forest areas by the Forestry Department of Ak-Tal village.

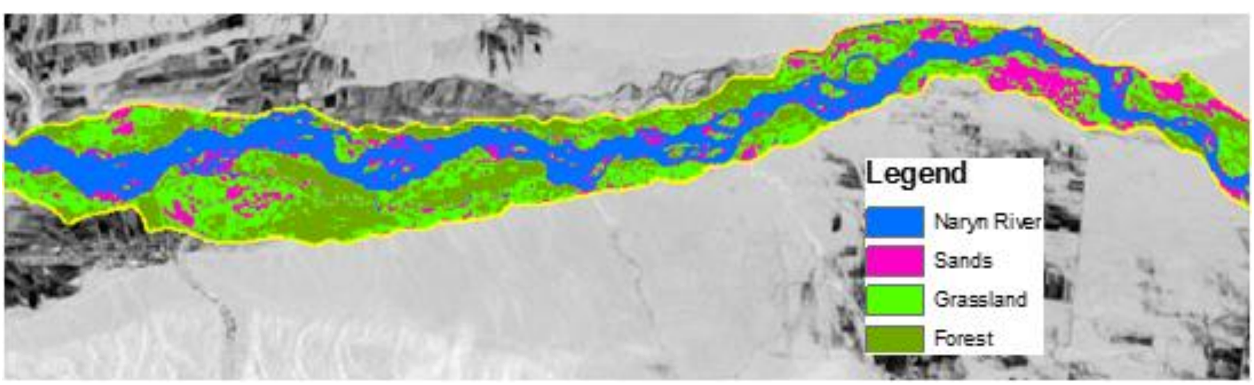

Figure 9: Floodplain forests near the Ak-Tal village of the Naryn River

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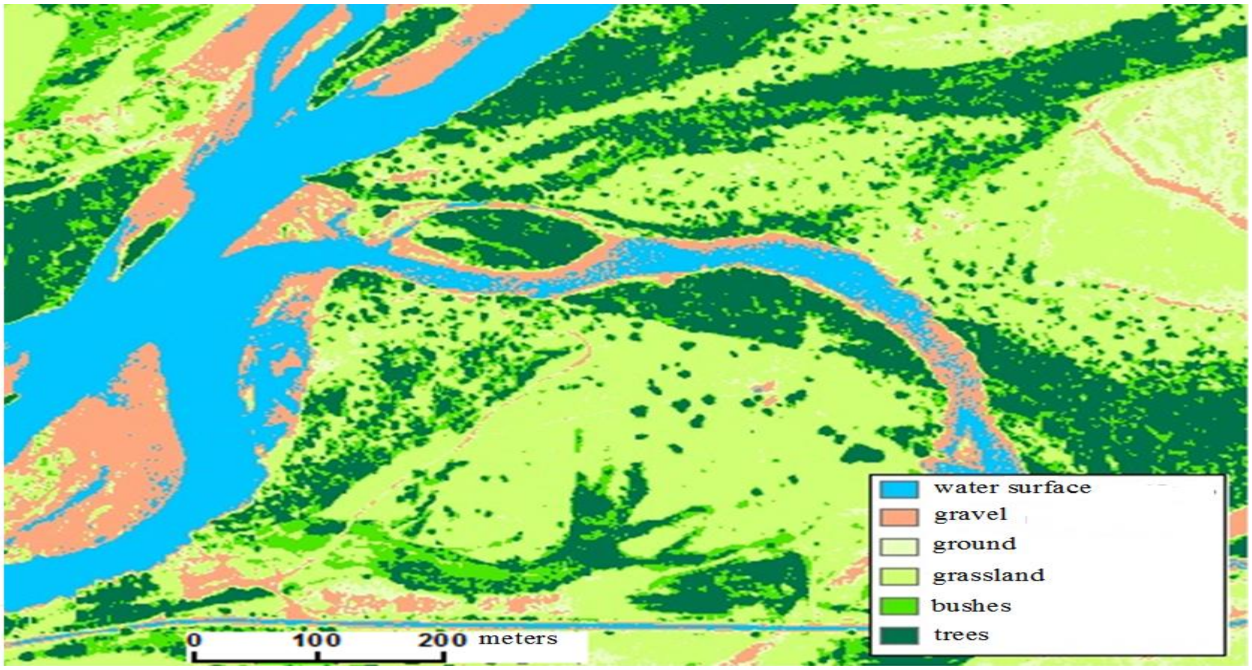

Figure 10: Mapping of ecosystem services of floodplain area of the Naryn River

Negative impacts of climate change on water resources show an increase in runoff and rising water levels in rivers during springtime (Figure 1 b, c) as a result of accelerated glacier melting. Furthermore, the intensity of precipitation increases (short-term) and extreme weather situations become more frequent. An alteration of hydrological regimes of snow and glacier-fed rivers changes the characteristics of hazards and risks in high-mountain regions. Therefore, the consequences of these anthropogenic impacts are in the form of flood risks and bank erosion (Figure 2 and 5). Additionally, rejuvenation and seed germination of woody floodplain species are affected (Figure 4). However, conservation of biodiversity and maintenance of forest ecosystem functions are significant in mitigating climate change consequences.

Discussion

Unmodified dynamics of rivers are represented by various forms like riffles, islands and branches. Along certain reaches, significant erosion is taking place close to settlements on the floodplains creating a certain potential for natural hazards. Resultantly, water erosion is changing the riverbed. The floodplain is submerged several times during flood events. Decrease of water levels after the flood and the deposition of sediments bring a new floodplain development and their modification over time. The curve of bank areas during floods receives sediments. Gradually this activity shifts the thalweg of the braiding river and modifies the water flow. In some places, gully erosion threatening the floodplain is observed.

The channel migration over the entire length of the Naryn River is characterized as multidirectional as shown in the figure 5. The direction of migration depends on where the concave bank erosion is most prominent. One of the reasons for the migration of the river through bank erosion and bed occurrence is the increased runoff caused by increasing glacier melt due to climate change (Sommer *et al*., 2013). Hagg *et al.* (2013) noted that the annual runoff in the basin of the Big Naryn increased by 3.7 mm per decade. This is due to an excess of water resulted from the degradation of glaciers, which contributed about 8% of annual flow in the second half of the 20th century. They mentioned that the results show a current glacier volume of 26.0–33.3 km³. A total of 6.6–8.4 km³ (20%) have been lost since the mid-20th century. The water

equivalent of 5.9–7.6 km³ was transformed into excess discharge and contributed to at least 7.3–9.2% of total runoff in the considered period.

The reach boundaries shown in figure 2 reflect the altered balances of flow and sediment in the downstream of the river. According to Thorndycraft, Benito and Gregory (2008), river channels show combined effects of the migration, incision and alteration concerning a wide variety of spatial and temporal scales. Important to take into account are the effects of climate change, anthropogenic impacts and tectonic movements for interpreting fluvial processes related to the different forms of sedimentation and erosion. As shown in figures 3 and 4, the patterns of fluvial activity are determined by deposit landforms such as bars and islands. These geomorphological units can serve as potential habitats for floodplain vegetation.

The bank movement rates of the right and left sides of floodplain areas show a mean of 0.8 m/a for one year. Anthropogenic pressure on the floodplain like timber harvesting and gravel mining or grazing, as well as climate change, increases the bank migration. Floods have a key role in re-shaping the sediment transportation and, thus, the channel of the Naryn River. Increasing the water flow rate and flow depth in the flood period is accompanied by the transport of suspended sediment. This sediment is deposited in the floodplain area and accumulated on its banks as a part of the river. Human impact to the floodplain areas causes a considerable loss of vegetation and land from the channel banks. Sustainable floodplain forest management reduces the destructive properties of Mountain Rivers, as vegetation reduces the stream forces and increased resistance against water erosion (Hupp, 1992; Tabacchi *et al*., 1998). Water slows down with the change of water depth in the floodplain and flow encounters resistance from the roughness of its surface.

Conclusion

The floodplain regulates water discharge and, thus, prevents flood occurrence downstream. The study and understanding of the floodplain ecosystem role in river flow helps predict extreme flooding situations and provides advance warning of their occurrence. Rehabilitating the natural function of floodplains increases vegetation cover, promotes the possibility of the bank areas accumulating deposits of sediment. These activities foster the local resistance against water erosion during the flooding periods. During the high water levels of flood times, the floodplain distributes discharge into the riverbed structures and regulates the river flow, which is important for the control of water erosion. In addition, the excess sediment load in the river affects the water quality.

Recommendations for sustainable use of forest of the floodplain areas are:

- development of a rule for the regulation of forest use,
- organizing of a local tree nursery,
- the appointment of a responsible person,
- control of the forest use and rotation of areas in forest use.

The map of ecosystem components of floodplain areas serves as the basis for forest management and planning for renewable activities for increasing biological diversity, and also for analyzing the provision of ecosystem services and how they affect the state of natural resources, climate change.

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References

Aizen, V., Aizen, E. and Melack, J. (1995). Climate, snow cover, glaciers, and runoff in the Tien-Shan, Central Asia. *Water Resources Bulletin*, 31: 1113-1129.

Benjarkar, R., Egger, G., Jorde, K., Goodwin, P. and Glenn, N. (2011). Dynamic floodplain vegetation model developed for the Kootenai River, USA. *Environmental Management*, 92: 3058-3070. DOI: https://doi.org/10.1016/j.jenvman.2011.07.017.

Brandt, S. (2000). Prediction of downstream geomorphological changes after dam construction: a stream power approach. *Water Resources Development*, 16: 343–367. DOI: https://doi.org/10.1080/713672510.

Collins, B. and Montgomery, D. (2002). Forest development, wood jams, and restoration of floodplain rivers in the Puget lowland, Washington. *Restoration Ecology*, 10(2): 237-247. DOI: https://doi.org/10.1046/j.1526-100X.2002.01023.

Downs, P. and Thorne, C. (2000). Rehabilitation of a lowland river: Reconciling flood defense with habitat diversity and geomorphological sustainability. *Environmental Managementi*, 58: 249-268.

Fryirs, K. and Brierley, G. (2013). *Geomorphic analysis of river systems: an approach to reading the landscape*. West Sussex, UK: John Willey & Sons Press.

Gregory, K., Macklin, M. and Walling, D. (2006). Past hydrological events related to understanding Global Change: an ICSU research project. *Catena*, 66: 2–13. DOI: http://dx.doi.org/10.1016/j.catena.2005.11.011.

Hagg, W., Mayer, C., Lambrecht, A., Kriegel, D. and Azizov, E. (2013). Glacier changes in the Big Naryn basin, Central Tian Shan. *Global and Planetary Change*,110: 40–50. DOI: http://dx.doi.org/10.1016/j.gloplacha.2012.07.010.

Harrison, L. and Keller, E. (2007). Modelling forced pool–riffle hydraulics in a boulder-bed stream, southern California. *Geomorphology*, 83: 232–248. DOI: http://dx.doi.org/10.1016/j.geomorph.2006.02.024.

Hupp, C. (1992). Riparian vegetation recovery patterns following stream channelization: a geomorphic perspective. *Ecology*, 73: 1209-1226.

Hupp, C., Pierce, A. and Gregory, B. (2009). Floodplain geomorphic processes and environmental impacts of human alteration along coastal plain rivers, USA. *Wetlands*, 29: 413–429. DOI: https://doi.org/10.1672/08-169.1.

Jasiewicz, J. and Metz, M. (2011). A new GRASS tool kit for hortonian analysis of drainage networks. *Computers and Geosciences*, 37(8): 1162-1173. DOI: https://doi.org/10.1016/j.cageo.2011.03.003.

Junker, B. and Buchecker, M. (2007). Aesthetic preferences versus ecological objectives in river restorations. *Landscape and Urban Planning*, 85: 141-154. DOI: https://doi.org/10.1016/j.landurbplan.2007.11.002.

Kenneth, N. and Brooks. (2003). *Hydrology and the management of watersheds*. Ames, Iowa: Blackwell Publishing Professional Press.

Kriegel, D., Mayer, C., Hagg, W., Vorogushyn S., Duethmann D., Gafurov A. and Farinotti D. (2013). Changes in glacierisation, climate and runoff in the second half of the 20th century in the Naryn basin, Central Asia. *Global and Planetary Change*, 110: 51-61. DOI: http://dx.doi.org/10.1016/j.gloplacha.2013.05.014.

Kummu, M., Lu, X., Rasphone, A., Sarkkula, J. and Koponen. J. (2008). Riverbank changes along the Mekong river: remote sensing detection in the Vientiane-Nong Khai area. *Quaternary International*, 186: 100–112. DOI: https://doi.org/10.1016/j.quaint.2007.10.015

Makkaveev, N. (1998). *Erosion-accumulation processes and topography of the river bed*. Moscow: MSU Publishing House.

Merritt, D. and Wohl, E. (2003). Downstream hydraulic geometry and channel adjustment during a flood along an ephemeral, arid-region drainage. *Geomorphology*, 52: 165–180. DOI: https://doi.org/10.1016/S0169-555X(02)00241-6.

Schiemer, F., Baumgartner, C. and Tockner, K. (1999). Restoration of floodplain rivers: the 'Danube restoration project'. Regulation River: *Restoration Management*, 15: 231-244.

Simon, A. and Collison A. (2002). Quantifying the mechanical and hydrological effect of riparian vegetation on streambank stability. *Earth Surface Processes and Landforms*, 27: 527-546. DOI: https://doi.org/10.1002/esp.325.

Sommer, R., Glazirina, M., Yuldashev, T., Otarov, A., Ibraeva, M., Martynova, L., Bekenov, M,. Kholov, B., Ibragimov, N., Kobilov, R., Karaev, S., Sultonov, M., Khasanova, F., Esanbekov, M., Mavlyanov, D., Isaev, S., Abdurahimov, S., Ikramov, R., Shezdyukova, L. and Pauw, E. (2013). Impact of climate change on wheat productivity in Central Asia. *Agriculture, Ecosystems and Environment*, 178: 78–99. DOI: https://doi.org/10.1016/j.agee.2013.06.011.

Tabacchi, E., Correll, D., Hauer, R., Gilles, P., Planty-Tabacchi, A. and Wissmar, R. (1998). Development, maintenance and role of riparian vegetation in the river landscape. *Freshwater Biology*, 40: 497-516.

Thorndycraft, V., Benito, G. and Gregory, K. (2008). Fluvial geomorphology: A perspective on current status and methods. *Geomorphology*, 98: 2–12.

Tockner, K., Schiemer, F. and Ward, J. (1998). Aquatic conservation: Marine and freshwater ecosystems. Aquatic Concerv: *Mar.Freshw.Ecosyst.*, 8: 71-86.

Wohl, E. (2005). Human impacts to mountain streams. *Science Direct*, 79: 217-248. DOI: https://doi.org/10.1016/j.geomorph.2006.06.020.

Doi: https://doi.org/10.33002/nr2581.6853.050105
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Authors' Declarations and Essential Ethical Compliances

Authors' Contributions (in accordance with the ICMJE criteria for authorship)

Contribution	Author 1	Author 2	Author 3	Author 4	Author 5	Author 6	Author 7	Author 8
Conceived and designed the research or analysis	Yes	Yes	No	No	Yes	Yes	Yes	Yes
Collected the data	Yes	Yes	No	No	Yes	Yes	Yes	Yes
Contributed to data analysis & interpretation	Yes	Yes	Yes	No	No	Yes	Yes	Yes
Wrote the article/paper	Yes	Yes	Yes	No	No	Yes	No	Yes
Critical revision of the article/paper	Yes	Yes	No	Yes	No	Yes	No	Yes
Editing of the article/paper	Yes	Yes	No	No	No	No	No	Yes
Supervision	Yes	Yes	No	No	No	No	No	Yes
Project Administration	Yes	Yes	No	No	No	No	No	Yes
Funding Acquisition	No	No	No	No	No	No	No	Yes
Overall Contribution Proportion (%)	20	20	5	5	5	18	7	20

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Research involving human bodies (Helsinki Declaration)
Has this research used human subjects for experimentation? No

Research involving animals (ARRIVE Checklist)
Has this research involved animal subjects for experimentation? No

Research involving plants
The research did not involve plant species.

Research on Indigenous Peoples and/or Traditional Knowledge
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